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INTERPRETATION OF THE FORMATIONS CONTAINING HUMAN BONES AT VERO, FLORIDA

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The formations of the locality involved in the interpretation of the age and relations of the fossil remains of man found near Vero, Florida, have been clearly described in the preceding paper by Dr. Sellards. The surface aspect of the region is plane and flat, relieved slightly by low beach ridges, gently rising dunes, and shallow drainage flats, none of which are impressive features of the landscape, though all contribute valuable criteria to the interpretation. In its immediate bearings on the problem raised by the occurrence of human remains mingled with extinct vertebrates, the critical feature of this plain is the broad, shallow valley of Van Valkenburg's Creek, whose former course—now much obscured by the recently dug drainage canal—is indicated in Figs. 1 and 2. It was in the bottom deposits of this wide stream channel, or in those of its predecessor, that the human bones in question were found. The past workings of this stream, therefore, require the

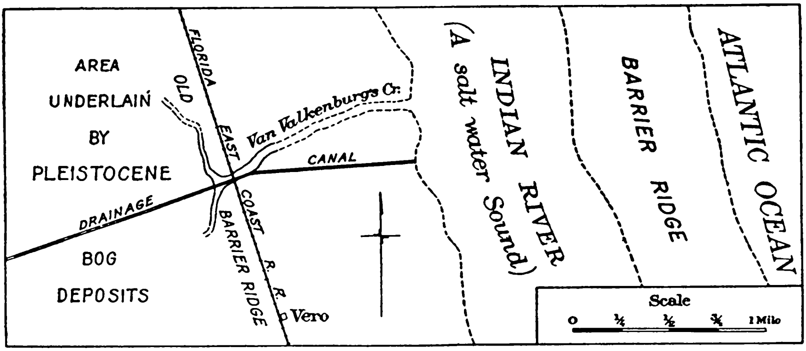

FIG. 1.—Rough sketch showing merely the general relations of the features discussed in the text.

closest scrutiny. But before attempting to interpret the history of the stream, let us review briefly the geologic section at Vero, though we have little occasion to depart from the careful description of Dr. Sellards.

Beneath the stream deposits, as well as beneath the whole region under consideration, the oldest beds exposed to view belong to the Anastasia formation, a striking marine shell marl, often known as "coquina" rock. Composed almost entirely of shells, in most cases but little fragmented, its identity is always clear, and it thus affords a most excellent datum plane at the base of each section studied. It is Dr. Sellards' formation No. 1, and is assigned to the Pleistocene. In its upper portion it grades into beach sands containing here and there lenses and streaks of shells, and these, in turn, pass upward almost imperceptibly into fresh-water or wind-blown sands. This formation underlies both the area of Van

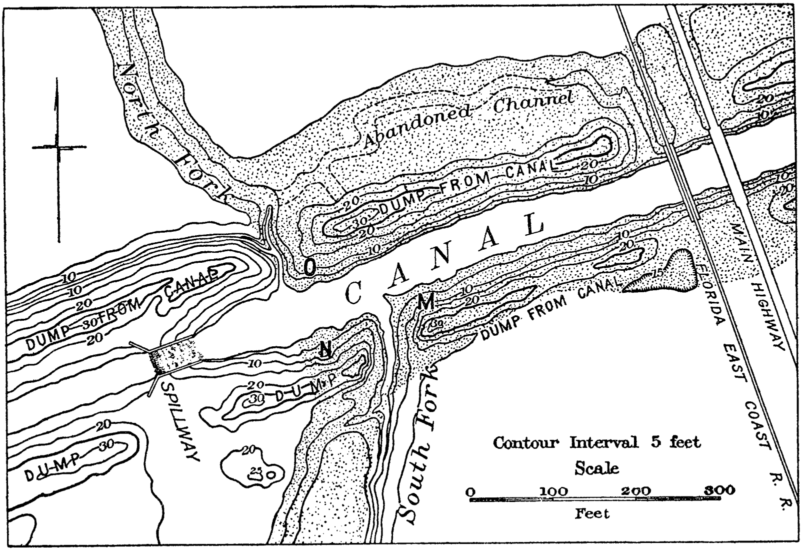

FIG. 2.—Detailed map of the locality where the human bones were found. The canal and the resulting dump piles have done much to change the original topography. The dotted area represents the flood plain of Van Valkenburg's Creek as its appears to have been just prior to the digging of the canal. The first human skeleton was found in formation No. 2 at point marked *M*, the second at point *N*, while human relics were found in formation No. 3 at point *O* as well as also near *N*.

Valkenburg's Creek and the adjacent country, and thus far the sections are the same, but above this horizon the channel section and the upland, or country, section are totally unlike and will be described separately.

THE SECTION OF THE CREEK BOTTOMS

This is the section described by Dr. Sellards. It is now well exposed in the walls of the drainage canal which, for several hundred yards, cuts through the deposits of the old creek bottoms. Resting upon the eroded surface of formation No. 1, sometimes lying directly upon the coquina rock, sometimes resting upon the beach sand, or shore phase of No. 1, is Dr. Sellard's formation No. 2. It is, as he has described it, a cross-bedded, river-washed sand, partly white, partly stained brown by organic matter, and containing partially decayed wood and muck. At the top, in places, there is a fresh-water, clayey marl. This formation contains human bones essentially *in situ*, beyond reasonable doubt, together

FIG. 3.—The drainage canal, looking southwest from the Florida East Coast Railroad bridge to the spillway.

with the scattered bones of many extinct vertebrates, as maintained in the previous paper. It is, therefore, the critical formation of the section, and upon its age and mode of origin the case of Pleistocene man stands or falls.

Above formation No. 2, and, at most points, sharply separated from it by a clear-cut line of erosion, is an alluvial deposit, formation No. 3 of Sellards. This is composed of swamp muck in many layers, interstratified with layers and lenses of coarse sand. Its top is the present flood-plain surface of Van Valkenburg's Creek.

INTERPRETATION OF THE CREEK SECTION

Following the deposition of the marine coquina, a withdrawal of the sea gradually brought this region into the horizon of terrestrial action. In the transition, beach conditions prevailed, resulting in sandy deposits, partly marine, partly terrestrial. These finally gave way to eolian sands. An interval of unknown duration followed. At some later time a stream occupying essentially the same course as that which, just prior to the construction of the canal, was followed by Van Valkenburg's Creek excavated a channel which, in some places, was cut through into the coquina. The notable width of this channel in proportion to its very shallow depth—which was limited by sea-level—suggests that erosive action was in progress for a considerable time at least. But as Dr. Sellards has remarked, tidal scour may have been an accessory factor in the development of the breadth of the channel. There are today in the strip of coast between Sebastian and Eau Gallie several such broad, shallow channels up which the tide runs. But if tidal scour is appealed to, it must be interpreted so as to be consistent with the fact that there were deposited in the Vero channel, not only muck and washed sands, but also human bones, together with many scattered bones from a variety of extinct vertebrates. The interpretation must also be in harmony with the specific fact that the human bones were found to be notably less scattered and fragmentary than the bones of the extinct vertebrates.

Some erosion of the surface of this No. 2 formation seems clearly to have occurred, since its upper surface is a sharp line, and this is most naturally interpreted as implying change of attitude or of relations, as well as an erosion interval. After such erosion it was covered by the alluvial deposit, No. 3. Because of the large proportion of muck, and the extremely rapid shifting from muck-accumulating to sand-depositing conditions, as revealed by the many alternating layers and lenses of sand and muck, this is interpreted as a flood-plain deposit. Its upper surface constituted the flood-plain of Van Valkenburg's Creek prior to 1913, when the drainage canal was dug.

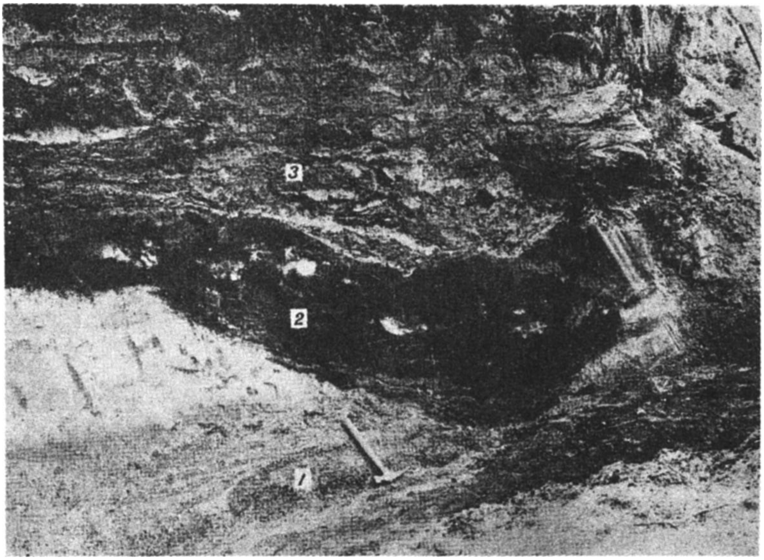

Fig. 4.—The creek section freshly exposed by cutting back into the south bank of the drainage canal at a point about 440 feet southwest of the railroad bridge: 1 represents the "coquina" rock grading upward into light-colored sands; 2 is Sellards' formation No. 2, which is here sand largely stained dark brown; note that it fills a trench cut in No. 1; 3 is Sellards' formation No. 3, consisting of alternating muck and coarse sands. Large log projects conspicuously on the right.

THE UPLAND OR COUNTRY SECTION

Downstream.—Though the surrounding country is not elevated, the general section outside the valley of the creek may be designated the upland, or country, section. Downstream from the locality where the human bones were found the country section adjacent to Van Valkenburg's Creek commences with the coquina rock at the bottom, just as does the section of the creek bottom. The coquina beds are followed by 2–5 feet of variously tinted sands. An orange-brown, ferruginous sand is a very persistent phase. These sands become dark-brown to blackish at the top, but are not very firmly indurated. At most points this sandy deposit forms the present surface, but in some isolated areas it is capped by a pondlike deposit of drab-colored, clayey, fresh-water marl. As this is being utilized for road material, the clay marl areas have been opened up to view and their extent is well known.

The south bank of the canal one-third of a mile east of the Florida East Coast Railroad bridge gives the following section:

o)	Drab-colored, clayey, fresh-water marl	3 ft.
n)	Dark-brownish, mottled sand, lighter colored below, getting darker above and at the top showing nearly black material, indicating an old soil line	2 ft.
m)	Marine shell marl (coquina)	1 ft.

The tract represented by this section lies nearer the coast than the locality where the human bones were found in the stream deposits, and hence has less specific bearing on our problem than the upland section of the tract adjacent to the creek *above* the critical locality.

Upstream.—The upstream section was found to be somewhat different from the coastward section as given above. Approximately 200 feet southwest (upstream) from the point where the human relics were discovered the waters of the drainage canal pass over a spillway and drop about 9 feet. This spillway is west of the junction of the two tributary branches of Van Valkenburg's Creek and lies outside the creek valley. For the first half-mile west of the spillway the canal has been cut through the following succession of beds:

d)	Pure-white, coarse-grained, wind-blown quartz sand	4–7 ft.
c)	Soft, spongy, peaty layer, containing many partially decayed roots; in places absent	0–6 in.
b)	Dark-brown to true-black, firmly indurated sand or sandstone; cemented by ferric hydroxide and organic matter, but the color of iron staining is largely obscured by the organic black	2–4 ft.

a) Brown sand gradually losing its dark stain and passing downward into a reddish-brown sand stained by iron oxide, and finally grading into a buff sand below, which is of finer grain than that above, and may possibly be marine	3–4 ft.

There is no sharp division between (*a*) and (*b*).

For at least another half-mile west the section changes in no essential feature except that the wind-blown sand (*d*) gradually thins until, at one mile from the spillway, there are barely two feet of it. The coquina rock does not appear above the water-level in the canal during the first mile west of the spillway, though it is said to reappear some distance farther west.

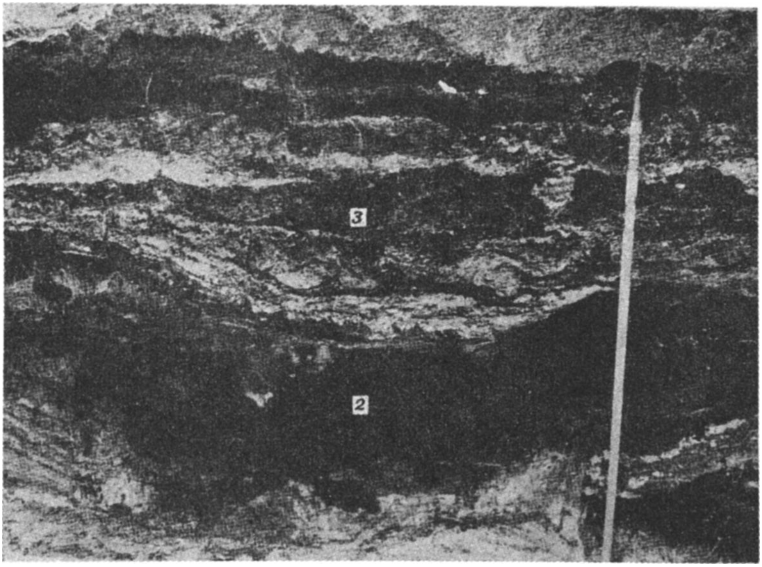

FIG. 5.—The creek section on south bank of drainage canal, 465–70 feet from the bridge. This face, now dug back many feet from the original drainage canal bank, is approximately the spot where the second human skeleton was found in formation No. 2 (marked *N* on map, Fig. 2). Formations Nos. 2 and 3 displayed.

INTERPRETATION OF THE UPLAND SECTION

Following the deposition of the marine coquina beds, semi-marine, semi-terrestrial beach sands, and, later, eolian sands accumulated to a thickness of perhaps 6–8 feet over much of the country immediately northwest of Vero. In spots the thickness was less, but at other points, no doubt, dunes as well as beach ridges made its total more than this. A widespread peaty layer at the top of this formation strongly suggests that, following the deposition of these sands, bog conditions existed for a period in the area west of the spillway. The upper two or three feet of the sands of layer *b* are very firmly cemented by iron oxide, and are deeply stained by organic matter, implying that this horizon constituted the subsurface for a long time. Iron oxide cement is, as is well known, common in bog deposits. A reason for an extensive wet area, or bog, to the west of the spillway is readily found in a broad beach ridge near the spillway which interfered with the drainage of the tract lying west (see Fig. 1).

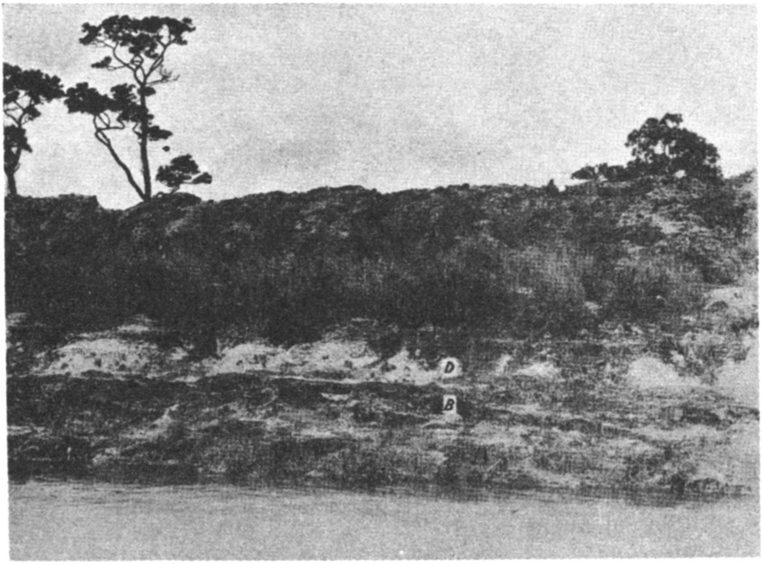

FIG. 6.—Section of uplands, exposed in north bank of drainage canal, one-third mile southwest of spillway: *B* represents layer *b*, consisting of indurated black sand or sandstone, capped in the left half of the picture by peat (layer *c*); *D* is layer *d*, white eolian sands, resting upon the Pleistocene bog surface. Above is the material excavated in making the canal.

The present coast, in a way, serves as an example of similar relations. The east coast of Florida is flanked by a barrier sand ridge for 300 miles; for over 100 miles the barrier incloses a strip of water between it and the mainland, known as the Indian River, though it is really a salt-water sound. Paralleling the present coastal barrier and the Indian River behind it is an older barrier ridge which crosses the canal near the spillway and runs for many miles both north and south of Vero. To the west of it, before the drainage canal was dug, the region was frequently under water after storms, according to testimony, and in earlier times it presumably was more continuously marshy, since it more nearly approached the present condition of the Indian River.

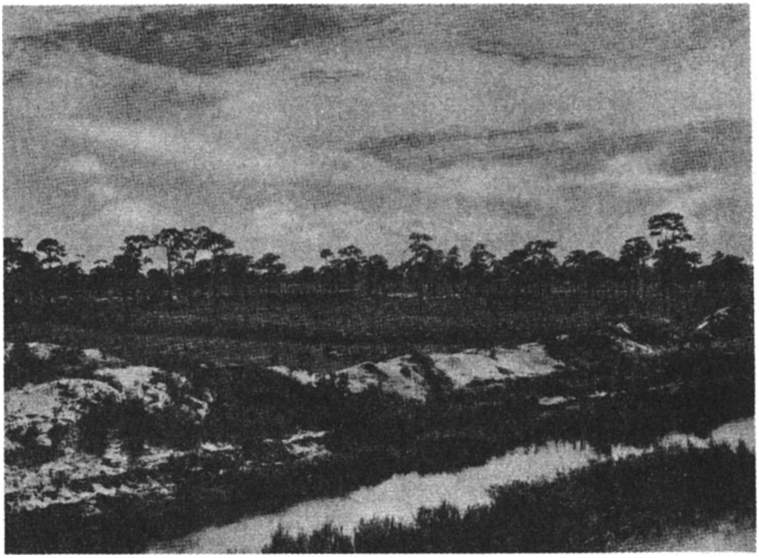

FIG. 7.—The present upland country southwest of the spillway. The area of the Pleistocene bog. Drainage canal in foreground with tributary canal in middle distance. Lumps of the black sandstone conspicuous upon dump piles of both canals.

But with uplift, or withdrawal of the sea, the marsh was gradually drained, and a thin covering of wind-blown white sand drifted over the old bog surface, burying it to a depth of several feet. This wind-blown sand forms layer *d* and constitutes the present upland surface.

CORRELATION OF CREEK-BOTTOM SECTION WITH UPLAND SECTION

For the complete history of the district it is necessary to correlate the creek-bottom section with the upland, or country, section. The coquina is common to both and serves as a base of reference. If we turn to the upland section as it is developed just west of the junction of the two forks of Van Valkenburg's Creek, we observe that the most striking feature there shown is the almost perfectly black, indurated sand bed, or sandstone, which forms a persistent layer, in places capped by peat, beneath the surficial wind-blown sands. If the creek deposits were younger than the induration of this sandstone, evidence of such relative age might well be found in the incorporation of derivatives from the black sandstone in the creek deposit, for, if the age and induration were considerable, the sandstone should have been of sufficient hardness to supply the two forks of the creek with pebbles and cobbles of this very easily recognizable material. Now an inspection of the freshly cleaned face of Dr. Sellards' formation No. 2—the critical formation—reveals the presence in it of many small pebbles, and not a few round "cannon balls," of this black sandstone (see Fig. 8). The latter range up to 5 inches in diameter. They are not confined to any one layer, but are scattered through No. 2 formation from top to bottom. Thus the formation in which the human bones and the extinct vertebrate remains were found also contains numerous pebbles and cobbles of black sandstone from the older formation! The stream which deposited formation No. 2 formed these pebbles of black sandstone by erosive action on stratum *b* of the upland section, through which both the north fork and the south fork of Van Valkenburg's Creek have obviously cut their stream channels. This black layer underlies apparently all the country immediately to the west of the spillway; it is a continuous, persistent layer; it was traced *in situ* to within 150 feet of where the human remains were found, and with further digging it could probably be traced still nearer. There is no other known source for the pebbles of black sandstone. *The conclusion seems, therefore, inevitable that Dr. Sellards' formation No. 2 is younger than stratum b of the upland section—the old bog surface upon which the peat accumulated.* Furthermore, it would seem to be considerably younger, inasmuch as the old bog-covered sands had, since their formation, endured for a time sufficient to permit their upper portion to become firmly cemented by iron oxide into a fairly indurated sandstone.

INTERPRETED HISTORY OF THE BONES

As is well described in Dr. Sellards' paper, human bones were found *in situ* in formation No. 2, in close association with scattered bones and fragments of bones from a great variety of extinct mammals, including the Columbian elephant, mastodon, saber-tooth tiger, tapir, armadillo, sloth, bison, camel, horse, etc. This vertebrate fauna, according to Dr. O. P. Hay,[1] would seem to represent the early Pleistocene. But it should be noted again that, while the human bones make up quite a part of two skeletons, the bones of the extinct vertebrates are fragmentary and extremely scattered. This fact, that the remains of the ancient vertebrates are

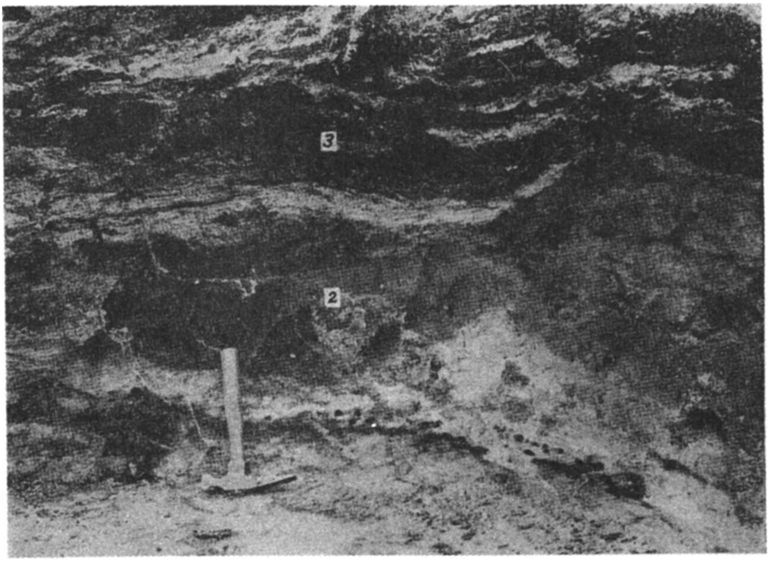

FIG. 8.—The creek section on south bank of drainage canal, about 460 feet southwest from railroad bridge. Many small pebbles (size of marbles) of black sandstone here form a band in the lower portion of formation No. 2.

[1] Personal statement on the ground.

very fragmentary, by itself suggests that they have been disturbed and transported to a greater or less extent. On the contrary, the human bones, so much less scattered as to indicate that they belong to distinct individual skeletons, imply that they have suffered much less disturbance.

The history of the bones seems to unravel as follows: For a long time during the Pleistocene there existed a marshy area of considerable extent immediately to the west of the present location of the spillway. Peat accumulated in the bog, forming layer *c* of the upland section. In the course of its growth, various animal remains of the time became incorporated. The large vertebrates were no doubt often mired, and left their bones in the bog. This is a familiar process.

During and following the accumulation of the bog and the bones, the upper portion of the sandy formation that lies beneath the peat (stratum *b*) became indurated to sandstone by the infiltration of iron oxide. At the same time it was stained black by the decomposition products of the decaying organic matter that lay over it.

With further passage of time the large land vertebrates, one after another, became extinct in the region. In the course of time also man appeared in Florida. At some time subsequent to the growth of the bog, probably as the result of a slight uplift, Van Valkenburg's Creek and its branches, or their antecedents, cut channels across the beach ridge and into the peat deposit, the two forks apparently following essentially the courses which they hold today. The drainage lines thus established cut, not only into the Pleistocene bog deposits, but into the sands beneath. With the draining of the bog and the adjacent land the movement of sand by wind action was perhaps facilitated, and the dune formation (layer *d*) which covers the old bog surface west of the spillway may have been formed during the drainage stage. It is not inconsistent, however, to suppose that it was formed before the drainage was established.

Later came the stages of partial filling of the creek channel. The first stage was occupied by the deposition of formation No. 2 of Sellards. The material for this formation was derived from the upland section drained by the creek, not a little of it from layer *b*, as shown by the pebbles of black sandstone. The whiter portion of the sands of the stream deposit may have come from either layer *a* or from layer *d* of the upland section. To layers *b* and *c* are assigned the bones of the extinct vertebrates together with the pebbles and cobbles of black sandstone. While this deposition of formation No. 2 was in progress, the human bones are believed to have received their first and only burial in connection with the stream deposit. The human bones should thus naturally be less scattered than the fragments of the mammals which had been shifted from their original location into the stream channel.

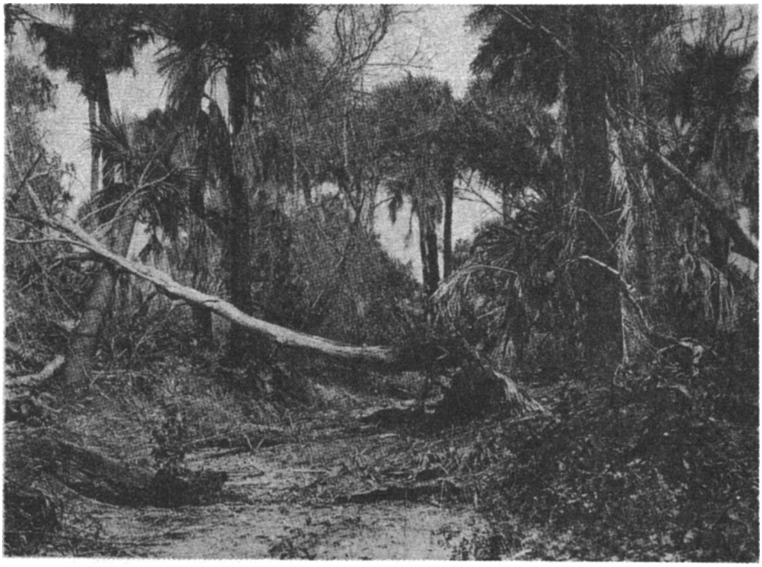

FIG. 9.—The present dry channel of Van Valkenburg's Creek just beyond the reaches of the drainage canal.

Following the deposition of formation No. 2 there was a period of erosion, either in the form of the ordinary scour-and-fill process of streams or as a result of ordinary subaerial denudation. A change in the stream conditions following the erosion stage caused a very heterogeneous alluvial flood-plain deposit (Sellards' formation No. 3) to be laid upon the irregular surface of formation No. 2.

Muck accumulated in alternation with layers of sand, as recurring floods from heavy tropical storms carried coarse material before them.

To this formation No. 3—just as in the case of formation No. 2—the upland bog area contributed many bones of extinct vertebrates as well as pebbles of black sandstone. At the same time human bones, pottery, and bits of flint (which does not outcrop in the region) were mingled with the flood-plain deposit, more or less directly, it would appear, as the result of human activity. There thus again came to be close assemblage of all this varied material in this formation, just as there had previously been in formation No. 2.

These conditions are interpreted as having been continued with little change (except on the human side) till the present, for pebbles of black sandstone and bones of extinct vertebrates are found *in the deposit of the present creek bed* into which formation No. 3 merges.

Two sets of evidence developed by Dr. Sellards need to be explained if we are to accept the sequence of events above outlined. Chemical analyses are cited as showing that the fossil human bones from No. 2 are quite as well mineralized as are the associated bones of the Pleistocene animals. Compared with a bone from an Indian mound near Vero, the chief difference is that the bones from No. 2 (human and other) have lost from 6 to 8 per cent of moisture and from 9 to 11 per cent of volatile matter. The loss of these easily eliminated constituents caused a proportionate increase in the percentage of calcium and phosphoric acid. But there was, in addition, an actual infiltration of silica, etc., from 0.4 to 2.9 per cent, and of iron and aluminum oxides from 0.6 to 3.5 per cent. While indicative of considerable age, it must be admitted that we do not know how rapidly bones are thus altered in sandy river beds when the adjacent sands contain abundant iron oxide.

A carapace of the turtle, *Terrapene innoxia* Hay, taken from formation No. 2 complete, though it was very fragile at the time of discovery, and the skull of a large wolf, *Canis ayersi* Sellards, are taken as evidence that the bones of the vertebrates were not transported from some other point by the creek. The turtle carapace was too fragile in the fossilized condition in which it was found to admit of stream transportation, though perhaps it could have endured transportation before fossilization. But if the interpretation of the history of the region be as outlined above, it would not seem unreasonable to suppose (in case it be definitely established that these species have been extinct in the region since the close of the Pleistocene) that the turtle carapace and the wolf skull, and other similar parts, had been subjected to a minimum of transportation wear because originally buried in the upland formation close to the spot where they were found, and that they were carried into the channel fill by the caving of the river bank, or some similar operation involving little wear. In no case was the transportation great. The other bones found in No. 2 and No. 3, in the opinion of the writer, give as much evidence of wear and polishing as would be expected of bones that were washed only short distances (from the upland bog to the places in the channel where they were found) by the flood stages of the creek.

Formation No. 3, therefore, seems to the writer to be very recent geologically, as it is the flood-plain alluvium of the present Van Valkenburg's Creek. The age of formation No. 2 can be determined less positively. It is simply older than No. 3 and younger than the Pleistocene bog deposits that lie west of the spillway, but it is the opinion of the writer that it is much nearer in age to No. 3 than it is to the Pleistocene bog accumulation and associated deposits which originally housed the old mammalian bones.